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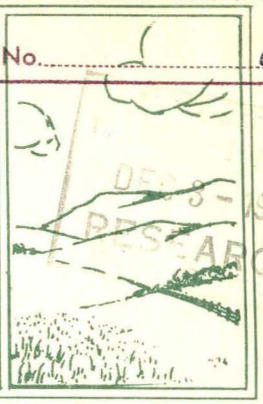

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HOW TO SOW MUSTARD IN BURNED WATERSHEDS OF SOUTHERN CALIFORNIA[1/]

By

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1/ Originally titled "Directions for Sowing Mustard for Erosion Control in Burned Areas of Southern California."

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INTRODUCTION

After the chaparral cover of the mountain watersheds in southern California is burned, damage is usually done during winter storms by increased runoff and erosion debris from the denuded area. The damage is done not only to the works of man, but to the watershed itself. Improvements that most often suffer tangible damage include water storage and diversion structures; roads, trails, railroads, and public utility lines; agricultural land, campgrounds, cabins, homes, and even whole communities. Other tangible losses are incurred through the wastage of flood water by-passed to the ocean because of its high silt content — water that would normally have been used directly or conserved in underground basins through water spreading grounds.

Damage is also done to other values, intangible as to dollar valuation but no less real. This includes such items as the deterioration of soil productivity through accelerated erosion in the burned area, interruption of communications, and the loss of human life.

Many years are required, under natural conditions, for regeneration of the plant cover and the restoration of normal runoff and erosion conditions. Many native chaparral shrubs sprout from their burned stumps or grow from seed soon after the fire, but through several growing seasons the soil between the shrub stumps may remain barren or develop only a thin cover of herbs and grasses.

For a "first aid" treatment to help recover and stabilize the barren soil, promote infiltration, reduce runoff and erosion, and thus lessen the damage from burned-area floods, some plant is needed that will make a quick growth. A practically unlimited supply of the seed of this emergency plant must be available at low cost on short notice. The plant must be able to withstand heat, drouth, and cold; it should reproduce itself for two or three years after sowing; and it should yield to the native cover when the native cover has regrown. Of more than a dozen selected plants tested by the Forest Service, common mustard has been found best in meeting these requirements in southern California.

Mustard sowing alone, however, can not wholly prevent damage from burned-area runoff and erosion; in fact, no plant cover can be established completely and quickly enough to afford the degree of soil stabilization that was exerted by the native vegetation before the fire. For full flood protection other preventive measures are required.

These measures may include the installation of debris basins at canyon mouths; check dams or other structures in stream channels; provision for better drainage along mountain roads; and the stabilization of road overcast and fill slopes. In some places the giving of

a flood-hazard warning may allow occupants of an endangered area to remove or otherwise protect improvements against damage. The detailed discussion of such measures is beyond the scope of this publication.

This revision of Research Note 37 has been written to help answer many requests for information on how to sow mustard received since the original Note was issued. Since that time, too, experience with airplane sowing has broadened, and sowing by helicopter has been tried for the first time. This new knowledge of the work has been incorporated in the present revision, which discusses the essentials of how to plan a mustard sowing job, how to conduct it, and how to judge its success. These three parts sum up the information needed for a complete job — thoroughly planned and fully recorded. On jobs involving only a few acres or those in which it is not desired to maintain a complete record of the work and its results, only applicable parts of the instructions need to be used. For agencies desiring to keep formal records of the work and its results, samples of the forms used by the Forest Service are available on request.

PLANNING THE JOB

Mustard seed needs only to be broadcast in the burned area. Because the seed germinates and grows readily in loose and ashy soil, no preparation of the ground in advance of sowing nor covering of the seed after sowing is required. This simplifies the job, both in planning the work and in doing the actual sowing.

The chief points in planning the sowing of a burn are: the sowing method to use, where and when to sow, and the seed requirements. Depending on the size and location of the job, such details as clearances from property owners or from agricultural agents, cooperative work, and release of news stories, may also require attention.

Sowing Methods; Rates and Costs

Mustard seed can be broadcast either by hand or by aircraft. It must be sown by hand when the most careful distribution of seed is required by a complicated pattern of land ownership. Hand sowing may also be required in isolated burns up to perhaps 500 acres in extent, which are so small that aircraft operators would not wish to bid on the job unless it could be done in connection with some nearby larger project. Or it may be done when ample manpower is available but there are no funds for aircraft hire. Sometimes, when seed and hand labor are immediately available, the sowing might be started by hand in order to get critical parts of the burn sown while arrangements are being made for aircraft service to finish the job.

Sowing by aircraft, which is especially adapted to large jobs, has proved less costly and much faster than sowing by hand. It also simplifies job administration by avoiding the transporting, housing,

feeding, instructing, and supervising of several of the workers necessary for hand sowing. For these reasons, sowing by aircraft is the preferable method.

Both the airplane and the helicopter have been used to sow mustard seed in burned areas. The airplane is best adapted to sowing large areas in solid blocks and of relatively gentle topography, where the speed and large pay load of the airplane make possible the fastest job performance. But the airplane can operate only from a rather sizeable landing field; it is unable to hug the ground in broken terrain; and its average distance above ground while sowing must be great enough to allow space for maneuvering at high speed. These characteristics, coupled with inherently fast flight and restricted view of the ground from the cockpit, require the use of ground flagmen to guide the airplane pilot and insure good seed distribution. Moreover, its flight characteristics make airplane operation hazardous in the rugged mountains where mustard frequently must be sown.

The helicopter has demonstrated its ability to fly very close to the ground, practically following the contour in canyons too deep, narrow, and tortuous for the airplane. The helicopter used to date had a pay-load capacity only $\frac{1}{4}$ to $\frac{1}{2}$ that of airplanes customarily used for such work, but it could land at convenient points in the burned area and take on more seed without loss of time. In fact, the frequent landings made the job easier by maintaining close personal contact between the pilot and the ground workers. The slow flying speed that is practicable with the helicopter was found to be a great advantage in mustard sowing. Coupled with the ability to fly close to the ground and excellent visibility from the pilot's seat, slow speed made possible good seed distribution without ground flagmen to guide the pilot. Moreover, the helicopter was judged to have a high safety factor for sowing mustard in rugged terrain; its slow flying speed lessened the chance of crashing into canyon walls, and it was able to land almost anywhere without a prepared landing field.

Sowing burned areas by aircraft is 10 to 30 times as fast as sowing by hand (table 1). In comparing the figures in table 1, it should be borne in mind that present data on the helicopter are drawn from the first use of this aircraft for mustard sowing, operating in some of the most rugged topography in southern California. On future jobs, improved seed loading techniques and better organization may increase the sowing rate for the helicopter.

Table 1.- Comparative rates of sowing mustard by airplane, by helicopter, and by hand.

Burned area, national forest, and year of sowing	Method of sowing	Area sown	Sowing time	Sowing rate
		Acres	Hours	Acres per hour
San Luis Rey burn, Cleveland, 1947	Airplane	1,000	3.17	315
Big Tujunga burn, Angeles, 1947	Helicopter	960	7.30	130
Indian Canyon burn, Los Padres, 1934	Hand-broadcast	2,700	1/ 240.0	2/ 11

1/ A crew of 20 sowers required 30 eight-hour days.

2/ Acres per hour covered by 20-man crew.

As of December 1947, the cost of sowing mustard in burned watersheds of southern California has been estimated at approximately $1.80 an acre by aircraft, and $3.95 an acre by hand (table 2). These costs of mustard sowing are the highest on record.

The 1947 estimates are from actual bids on a 1,000-acre sowing job. For this job, three helicopter bids were received; they ranged from $0.78 to $1.32 per acre and averaged $1.08 per acre. Eight airplane bids ranged from $0.73 to $1.85 per acre and also averaged $1.08 per acre. The job was actually done by airplane at the contract cost of $0.73 an acre for flying. The low bids for airplane and helicopter, both submitted by operators experienced in sowing mustard, were used in making the calculations for table 2. Costs of hand labor were estimated for a sowing rate of 5 acres per man-day, requiring 10 days for a 20-man sowing crew.

Table 2.- Comparative costs of sowing mustard by airplane, by helicopter, and by hand, based on airplane sowing of San Luis Rey burn, Cleveland National Forest, in December 1947.

Item	Cost and sowing method		
	Airplane	Helicopter	Hand
	Dollars		
Labor	1/ 891	2/ 919	3/ 2,475
Mustard seed 4/	704	704	704
Automotive equipment rental	5/ 15	6/ 12	7/ 53
Miscellaneous equipment	9	4	32
Total	1,619	1,639	3,264
Overhead 8/	32	33	326
Total	1,651	1,672	3,590
Contingency (10 percent)	165	167	359
Total project cost	1,816	1,839	3,949
Cost per acre	1.82	1.84	3.95

1/ Includes $727 flying contract and $155 for ground workers, plus 1 percent allowance for incidentals.

2/ Includes $785 flying bid and $125 for ground workers, plus 1 percent allowance for incidentals.

3/ Includes $2251 for hand labor and $84 for supervision, plus 6 percent allowance for incidentals.

4/ 3350 pounds of mustard seed at 1947 price of $0.21 per pound.

5/ 1 passenger automobile, 1 jeep, and 1 ½-ton pickup, 220 miles at $0.07.

6/ 1 passenger automobile, 1 jeep, and 1 ½-ton pickup, 165 miles at $0.07.

7/ 1 passenger automobile, and 1 ½-ton pickup, 350 miles at $0.07; and one 1½-ton stakeside, 200 miles at $0.14.

8/ Allowance for increased office work, such as extra payrolling and purchasing, required by the project. For hand-sowing jobs this is estimated at 10 percent of the direct costs; but on airplane and helicopter jobs the number of extra workers is so small and the job is so quickly done that an overhead allowance of only 2 percent is made.

Where to Sow Mustard

In general, a mustard cover would be beneficial in all recently burned areas in the chaparral type of southern California, especially when the potentiality exists for considerable flood and debris damage from the burn. Even though improvements are so situated that they may suffer little or no direct damage from flood waters and debris, it may still be desirable to sow mustard to hasten the establishment of protective vegetation in the burned area and lessen site deterioration. These are basic requirements of good watershed management for which mustard sowing is a relatively inexpensive aid. More specifically, the density of volunteer native plant growth, the condition of the soil, and the completeness of the burn will govern the sowing of mustard in burned areas.

Obviously, it would be undesirable to sow mustard in burned areas that had already developed an excellent cover of native herbs. Such growth might occur locally, particularly in burns of early summer within the fog belt near the ocean. By an "excellent" cover is meant herbs of the density and growth development to be expected of mustard in its first year; 5 or 6 plants per square foot, covering at least 75 percent of the soil when in the basal leaf stage, and growing to a height of 3 to 4 feet at maturity. If the native herb cover has less than this density or growth development (and experience has shown this to be the usual condition) it will usually be desirable to sow mustard.

Mustard grows best in areas of loose soil that were dominated before the fire by chaparral, sagebrush, or woodland, at elevations up to about 4500 feet above sea level. In such burns the seed should be sown over all slopes, regardless of steepness, exposure, or site conditions. If several months have elapsed since the fire, and rain has fallen, the surface mantle of loose soil and ash in some places may have been washed off or compacted; nevertheless, these places should be included in the sowing, along with other small areas in which the soil surface was barren and compacted before the fire. Such compacted areas are less favorable for mustard growth, but the survival of even a few plants will improve the cover.

Mustard is not usually sown in "patchy" burns, in which the unburned area greatly exceeds the burned area. Areas in which the fire burned lightly and only scorched the chaparral, leaving some foliage and a dense stand of shrub stems, do not require sowing, nor do rocky talus slopes that have little or no soil.

Mustard should not be sown in grassland, such as potreros or mountain meadows, because its introduction into such grazing areas is undesirable and the scorched sod usually gives adequate protection to the soil until the grass recovers. Nor should mustard be sown on slopes above agricultural land, particularly grain fields, in which the mustard might become a weed.

Burns that are more than 4500 feet in elevation, where winter temperatures are unfavorable for mustard growth, will usually not require sowing, although it may be desirable to sow burns in the chaparral type on warm southerly slopes up to about 5000 feet elevation.

In some burned areas sowing may be impracticable because the complex pattern of land ownership makes it impossible to obtain the consent of all the owners and get the job done before the winter rains set in. Obviously, mustard may not be sown on lands whose owners object to the introduction of this plant. In summary, then:

Sow mustard

1. In recently burned areas up to about 4500 feet elevation, where native herbs count less than 5 or 6 plants per square foot

Don't sow mustard

1. Where there is already a dense cover of native herbs, of growth form equal to mustard
2. Above 4500 feet in elevation, except for southerly exposures in chaparral
3. In "patchy" burns and areas only scorched by the fire
4. On slopes of rock talus
5. In potreros and mountain meadows
6. On slopes close above agricultural land
7. Where property owners object

When to Sow Mustard

To have the greatest chance for success, mustard sowing should be completed before the first winter rain. In southern California the first winter storms usually come in October or November and increase in frequency, amount, and intensity of rainfall to a maximum in February. Periods of warm weather suitable for plant growth usually follow the early storms. But December and January generally bring colder weather that is unfavorable for mustard growth, together with increased expectancy of the dry, northerly gales (called "Santa Anas") that sometimes desiccate even the hardy native plant growth.

Sowing before the first rains is desirable to take advantage of the uncompacted and ashy soil surface that is most receptive to seed. Early sowing also lessens the chances of the job being interrupted by bad weather, and permits the mustard plants to get well established before cold winter weather sets in.

Cold weather retards seed germination and inhibits plant growth. In fact, freezing temperatures that occur just after the mustard seeds have sprouted are likely to kill the tender seedlings; however, mustard plants that have reached a height of about 3 inches are quite hardy and have been observed to withstand temperatures as low as 22° F. Finally, late sowing may result in stunted growth and failure to produce volunteer seed, especially if rainfall is deficient in the late winter and spring. The record of 23 mustard sowing jobs from 1932 through 1946 shows that most of the burns sown after mid-December did not develop a satisfactory first-year mustard growth. For these reasons, all sowing should be finished by the middle of December.

If burns occur in the months August to November, the sowing must be organized to get the seed on the ground without delay. This requires quick action in planning the job and in buying seed, and sustained sowing effort.

When fires occur during the months January to July, the burns should not be sown until the following fall. Such burns should be examined in August to determine the need for sowing, as indicated by the density of natural vegetation and the condition of the soil.

Seed Requirements

Two kinds of mustard have been found particularly suited for use in burned areas of southern California. These are the cultivated variety of black mustard, Brassica nigra, and Montana Trieste mustard, a variety of Brassica juncea. Both species have several other common names (Appendix I).

Preference is given to Brassica nigra for burned-area sowing, as this seed is produced in southern California and is well adapted to local climatic conditions. The use of local seed also saves delivery time and shipping costs. In years when the supply of California seed is short or unusually high in price, Brassica juncea from Montana or the Pacific Northwest may be substituted.

Quality

The mustard seed should be high in germination, pure, and free of noxious weeds. Small lots (up to 100 pounds) can usually be obtained from a local seed dealer. Large quantities of seed are most advantageously bought on bid from the larger seed houses. The seed specifications used by the Forest Service require minimum germination

of 85 percent in 5 days, minimum purity of 97 percent, and freedom from primary and secondary noxious weeds as specified by the Agricultural Code of California. The dealer is asked to supply a notarized certificate that these specifications are met.

Offers have sometimes been received for odd lots of Brassica nigra or its wild variety at considerably reduced prices. Such bargain seed is usually obtained in the process of cleaning cereal grains. Either low germination or the presence of primary or secondary noxious weeds would disqualify such seed for use.

Amount of Seed to Sow

Mustard seed is sown at an average density of 20 seeds per square foot, which is equivalent to 5 pounds per acre when the seeds run 175,000 to the pound. Experience has shown that this amount of seed is required to yield 5 or 6 mature mustard plants per square foot after normal losses through failure of the seed to germinate and natural mortality among the young plants.

The number of mustard seeds per pound varies from about 150,000 to 600,000. This may not be important with only a small area to sow, but with large areas it will pay to make a field calculation of the pounds of seed to be sown per acre for each lot of seed (Appendix 2). Steepness of slope has a negligible effect on the rate of sowing, and this factor may be disregarded in calculating the overall sowing rate. Where rock occupies a considerable portion of the ground surface over large areas, the sowing rate can be reduced to the amount of seed required to cover the exposed soil at the proper density.

Delivery

Mustard seed produced in southern California is usually trucked to the job by the dealer. Seed produced in more distant places is usually shipped by freight to a dealer's warehouse in southern California. From there it can be trucked to the job. Details of delivery must be worked out in advance so that the delivery point can be specified in the invitation to bid.

On aircraft sowing jobs it is best to have the seed delivered direct to the airport or operations base, if this can be designated in advance, to avoid rehauling. If the operations base can not be specified, or if there is doubt as to whether the sowing will be done by aircraft or by hand, seed can be delivered at a point that best meets the requirements for safe storage and accessibility to the job. If seed storage at some point other than the base airport is decided on, it should be kept in mind that a single airplane can sow as much as 10,000 pounds of seed in one day, and that this supply will have to be maintained at the airport to avoid delaying the job.

Examining and Storing Seed

A few sacks of inferior seed have sometimes been included in a large order, notwithstanding the rigid specifications and the requirement that the dealer furnish a certificate guaranteeing conformance with the specifications. For this reason, it is wise to examine carefully all seed upon delivery, checking its weight and appearance as indicators of quality.

Bulk mustard seed is usually sold in 100-pound sacks. If the full sacks weigh only 85 or 90 pounds, the seed viability may be low and should be tested. Good mustard seeds are well filled, not shrivelled or wrinkled, and there are few empty hulls and half-seeds. The stems and foreign seeds that are the impurities commonly found in mustard seed can be readily seen with the naked eye.

If the sacks weigh close to 100 pounds and the seed appears good, it will usually be safe to sow, in view of the dealer's guarantee of quality. But if either the germination or purity is suspect, the seed should be withheld from sowing until its quality can be determined.

If seed purchased locally proves to be of doubtful viability or purity, the dealer will usually be glad to substitute good seed without question. If inferior seed is received from a dealer at some distance from the delivery point, however, it may be desirable to send a sample to the nearest seed testing laboratory for analysis and report,2/ as the basis for claiming restitution. (For instructions in seed sampling procedure, see Appendix 3).

Until the mustard seed is actually sown, it must be protected to prevent its deterioration through exposure to dampness. For a few days' storage on the job, a tarpaulin or tent cover, with poles or brush for a floor will usually give enough protection. On hand-sowing jobs in remote back country, care should be used to locate seed caches at accessible points where adequate protection can be provided in case of a storm. For long-time storage of large quantities of seed, a dry and well-ventilated warehouse is advisable, and the seed sacks should be stacked to allow free circulation of air.

2/ The California Seed Laboratory, of the State Department of Agriculture, at Sacramento, is fully equipped for this work. Germination and purity tests are made without charge for agencies of the State and Federal governments, and at a nominal fee for other agencies and private individuals. The services of private seed testing laboratories are also available in Berkeley and Los Angeles.

Clearances

Three types of clearances may be required from various authorities before mustard seed is sown in burned areas. These are concerned with operations on private land, weed control, and restrictions on the use of aircraft.

Operations on private land require permission of the owner, both for entry on the land and for the sowing of mustard. Residents of southern California usually have no objections to entry, but they have sometimes protested the use of mustard because they remember it as a serious pest in the Mid-west, where many of them formerly lived. Such objections are usually withdrawn when it is explained that there are no extensive grain fields in southern California close to the watershed areas in which mustard is sown, and that for many years mustard has been used as a cover-crop in citrus groves throughout that part of the state.

The weed control clearance is necessary (1) to avoid the introduction of mustard into areas where it might create an agricultural weed problem, and (2) as a check against the introduction of undesirable seeds along with the mustard seed. Such a clearance is issued by the County Agricultural Commissioner,3/ who usually requires only an explanation of the nature of the mustard sowing project, and a copy of the seed specifications.

Clearances governing the use of aircraft, such as obtaining permission to fly over military areas, are best provided for by making them the responsibility of the aircraft contractor when calling for bids on the job.

Cooperation and Publicity

When large areas are to be sown usually one or more public agencies, as well as private landowners, will be concerned with any plans for erosion-control treatment of a burned area. Interested parties may include the local water company, flood control districts, flood control survey groups, State and County foresters, Forest Service, Soil Conservation Service, or other Federal agencies, soil

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3/ Offices of the County Agricultural Commissioners in southern California are located as follows:

Los Angeles County	808 N. Spring Street, Los Angeles 12
Orange County	221 Courthouse Annex, Santa Ana
Riverside County	Courthouse, Riverside
San Bernardino County	Courthouse, San Bernardino
San Diego County	402 Civic Center, San Diego 1
Santa Barbara County	Courthouse, Santa Barbara
Ventura County	Agricultural Building, Santa Paula

conservation districts, and organizations of farmers and stockmen. The local County Farm Advisor should also be told of the plans.4/ All such agencies should be informed of the objectives of the mustard sowing, and they may wish to cooperate in doing the work.

Experience has shown that there is need for care in giving out news stories to avoid imparting the idea that mustard alone can prevent floods. It should be made clear that mustard sowing is an emergency practice in watershed management intended to increase the plant cover in the burned area, but that other measures such as the installation of debris basins will usually be required for full protection against floods.

DOING THE JOB

Equipment, techniques, man-power requirements, and individual responsibilities vary with the sowing method. The objective of all methods, however, is to get the seed evenly distributed at the proper density and at the proper time over the areas designated for sowing. Hand-sowing proceeds slowly and requires techniques and equipment with which most workers are familiar. Sowing by aircraft, which is especially adapted to large areas, is fast, requires more elaborate equipment, and utilizes techniques with which many field men are unfamiliar. To get the proper seed distribution and avoid delays, close attention to a number of operating details is required when sowing by aircraft. Hand-sowing is here discussed first and is followed by a general description of sowing by aircraft; detailed suggestions for sowing by aircraft are given in Appendix 4.

Sowing by Hand

The size of the crew for hand-sowing jobs will be determined by the area to be sown, the urgency of completing the job, and the number of foreman available. Experience has shown that one foreman can supervise about 25 sowers.

4/ Offices of the County Farm Advisors in southern California are:

Los Angeles County	808 N. Spring Street, Los Angeles 12
Orange County	1104 W. 8th Street, Santa Ana
Riverside County	Postoffice Building, Riverside
San Bernardino County	Federal Building, San Bernardino
San Diego County	404 U.S. Customs Building, San Diego 1
Santa Barbara County	Federal Building, Santa Barbara
Ventura County	52 N. California Street, Ventura

In estimating the size of crew required and the length of job, a sowing rate of 5 acres per man-day has been found advisable to allow leeway for unforeseen delays. Actually, however, ground crews have averaged about 7 acres per man-day in moderately rough country, while a maximum of 10 acres per man-day has been attained. The acreage sown per man-day will naturally depend on the amount of travel time and the number of hours worked, the 7-acre figure allowing 1 hour in travel during an 8-hour day.

For ground work it has been found best to divide the burned area into component drainage units, which may range in size from 25 acres to perhaps 400 acres. Small crews of 2 to 5 men and a strawboss are given full responsibility for sowing these drainage units. In sowing, the men walk back and forth across the slope on contour, starting at the top of the slope and working downward, broadcasting swaths about 20 feet wide. Some precipitous slopes too steep to climb over contain benches of erosible soil on which a protective cover of mustard is needed. These slopes can generally be sown by throwing handfuls of seed from the top and sides.

Special treatment to make the seed stay on the slope instead of rolling to the bottom can be given on loose, sliding cones of soil and on road overcast slopes. This treatment consists of having the men work across the slopes on contour lines 3 to 4 feet apart, slope distance, taking short steps and sowing as they go. By this method, most of the mustard seed will ultimately lodge in the men's footprints. To avoid excessive density of the mustard plants, the quantity of seed sown should be reduced to about 1 pound per slope-acre.

While the sowers are at work, the foreman should make spot checks of seed distribution by counting the number of seeds on the ground in selected areas to be sure that the density is about 20 seeds per square foot. A daily check should be made of the acreage sown and the amount of seed used, following the general method outlined in the detailed suggestions for aircraft sowing (Appendix 4).

Transportation of the seed to the sowing point is governed by conditions on the job. In remote areas, a few pack animals to carry supplies of seed to points convenient for the sowers may facilitate the work. Generally, however, each man carries his day's seed supply with him. Where there are sufficient roads, time and effort will usually be saved by having the sowers hauled to the top of the mountain by truck in the morning and picked up at its foot after the day's work.

The equipment needed for each sower includes a knapsack to carry a day's supply of seed. From 25 to 50 pounds may be carried, depending on the topography and distance of the sowing area from the base camp or truck. For measurement each sower also carries a one-gallon can (No. 10 size), which holds approximately 5 pounds of mustard seed, enough for one acre. The seed is broadcast by hand because mechanical seeders have been found impractical for use on the steep slopes usually encountered in burned areas.

Sowing by Aircraft

Whether mustard seed is sown by airplane or by helicopter,[5/] for the safety of the pilot and for uniform seed distribution, aircraft sowing should be done in calm weather. As the winter season approaches, good flying weather may be limited to a few hours each morning, from daybreak to about 10 a.m. Sometimes conditions again become suitable for flying in the late afternoon and evening. If it is urgent that a job be completed before an impending storm, the pilot may be willing to fly in less calm weather or for longer hours. It is important to remember, however, that the pilot should be free at all times to decide when he will fly and how he will cover the area. He alone knows what he and his aircraft can do.

With either type of aircraft, the basic problems involve broadcasting the seed with maximum uniformity over the burned area, and doing the job as rapidly as possible commensurate with safety and proper distribution of the seed. The equipment, landing-field requirements, flying techniques, and man-power needed differ according to the type of aircraft used. (Specifications for aircraft service are given in Appendix 5.)

Equipment

Open cockpit or cabin type airplanes which have a capacity from about 500 to 1500 pounds of seed are customarily used to sow mustard. Such planes are in regular use for crop-dusting and rice-sowing operations and require only minor changes to adapt them for mustard sowing. Special equipment required for sowing includes a seed hopper built into the plane, gates for controlling the flow of seed from the hopper, and a Venturi flume mounted beneath the fuselage to spread the seed evenly. Seed flows by gravity from the hopper into the Venturi flume, where it is swept away by wind from the propeller. The flow of seed is controlled by a release gate to start and stop the flow, and a metering gate to control the rate of flow. Both gates are operated from the pilot's cockpit. The concentration of seed sown is governed by the setting of the metering gate and the speed of flight.

5/ Mustard seed was first sown in burned areas by airplane on Los Padres National Forest in 1932 and 1934. The next airplane sowing was done on the San Bernardino National Forest in 1940 and 1941, followed by additional work on the Cleveland, San Bernardino, and Angeles National Forests in 1943 and 1947. The helicopter was first used to sow mustard on the Angeles National Forest in October 1947.

A two-place helicopter with open cockpit was used for the mustard sowing.6/ The pay load of this helicopter with standard equipment was 400 pounds maximum. As altitude increased, however, it was necessary to reduce the pay load in order to improve flying performance, especially on hot days. The maximum working altitude at which this model helicopter could take off with load, hover, and land was approximately 5500 feet. Once aloft, however, the machine could continue in flight with a load at altitudes of over 10,000 feet, so long as sufficient air speed was maintained. On the Big Tujunga burn of 1947, sowing was done up to an altitude of 4000 feet, carrying as much as 330 pounds of seed. The pilot reported that the aircraft handled satisfactorily above 5400 feet with from 180 to 220 pounds of seed in the hoppers.

The helicopter was equipped with twin hoppers and tube assemblies for carrying and spreading the seed. As in an airplane, the flow of seed was controlled by release and metering gates in the bottom of the hoppers, and the rate of sowing depended both on the setting of the metering gate and the speed of flight.

Landing-field Requirements

For safe operation, the airplanes used for mustard sowing require a fairly smooth and level landing field at least one-half mile long. Other conditions being equal, a landing field at low elevation is preferable to one at high elevation because of the greater density of the air at low altitudes and the resultant increase in "lift" for taking off with a load of seed.

The helicopter, by contrast, can operate from any plot of ground that is free of obstructions for a distance great enough to clear the rotors, i.e., a minimum diameter of about 50 feet for the helicopter used in 1947. As with airplanes, lower elevations are preferred for the operations base, except that in some cases a ridge top might be better than an adjacent canyon bottom because of the increased maneuvering room and benefit of increased "lift" from the wind. Location of the operations base for a helicopter must be determined by the pilot.

Flying Techniques

Best sowing results with the airplane have been obtained by flying not more than 300 feet above the ground, at a speed of about 90 m.p.h. Under these conditions the airplane most recently used sowed a swath 80 feet wide at the desired average density of 20 seeds per square foot. Cross-sowing the burn in strips at right angles to improve seed distribution has been found unnecessary.

6/ The helicopter was a Bell agricultural model 47B3.

Because of the airplane's fast flight and the necessity for making wide turns, it is advantageous to divide the burned area into rather large units that can be covered by a series of long, parallel, straight swaths at a safe distance above terrain, with a minimum of turns. Ground flagmen working in the sowing area and markers along its boundaries are usually needed to help the pilot cover the area completely without skipping or excessive swath overlapping.

With the helicopter, the best sowing results were obtained by flying about 50 feet above the ground, at a speed of 30 m.p.h. The width of swath sown was 60 feet and the seed density averaged 20 seeds per square foot with highly uniform distribution.

The helicopter's flight characteristics made it possible to sow the burned area by small watershed units, up to about 250 acres in extent, thereby concentrating the ground personnel in a small area. Flight tests showed that flying on contour and working downward from the head of a drainage was the easiest method of covering the area, owing to lessened power requirements. It was also found that the pilot had an unrestricted view forward, downward, and to the sides. Consequently, he could fly by ground landmarks, such as rocks and burned shrubs, and obtain uniform seed distribution without the aid of flagmen. Boundary markers were dispensed with by having the sowing foreman make a flight over the area with the pilot just before it was sown, to point out the boundaries and give any special instructions needed. All these techniques combined to make the results of sowing by helicopter approach a degree of selectivity and uniformity possible heretofore only through hand-sowing.

Man-power Requirements

An effective crew on an aircraft sowing job of 1,000 acres should include a foreman, two flagmen (if the sowing is done by airplane), two ground checkers to check seed distribution in the burned area, a truck driver, and one or two men at the operations base to help load the aircraft. These men are needed in addition to the pilots and mechanics who operate and service the aircraft.

In burned areas larger than 1,000 acres the number of flagmen required will be governed by the size, shape, and topography of the sowing area; at least two will be needed, and more may be desired by the pilot. It will also be desirable to have more ground checkers, so that at least 10 percent of the area can be sampled.

JUDGING THE SUCCESS OF THE JOB

The success of a mustard sowing project must be judged in terms of the mustard crop itself. The criteria to use are the uniformity and density of the mustard cover, and the height of stand obtained.

Good first-year mustard stands in the past have been evenly distributed and have averaged 200,000 mature plants per acre, with an average height of 3 to 4 feet, in more than 90 percent of the area designated for sowing. The litter produced by such a stand has been measured at $2\frac{1}{4}$ tons per acre (oven-dry weight). This density and uniformity of stand should be taken as the desirable objective. However, mustard sowing projects have been considered satisfactory if the first-year stand averaged 25,000 plants per acre in 75 percent of the area designated for sowing.

A dense second-year mustard growth usually develops from volunteer seed, even though the first-year mustard stand may have been sparse. In such a case, the project might become highly successful in the second year. Thus, "success" should be judged in terms of mustard growth and distribution in both the first and second years after sowing.

In experience to date, the most serious cause of unsatisfactory mustard growth has been careless sowing, this factor having proved even more critical than unfavorable growth conditions. Obviously, mustard can not be expected to grow where the seed is not sown. In areas where good seed was sown, some mustard has always grown to maturity; never has the entire crop been lost. For success, careful sowing to insure complete coverage of the area with seed is of the utmost importance.

Mustard Growth Examinations

Information on the growth and distribution of mustard is best obtained through field examinations made when the mustard is in full flower, usually in April or May. At this time the mustard can be identified at a distance by flower color. By counting the plants in a few sample stands of different color and appearance, a man can quickly develop judgment that will enable him to estimate the number of plants per milacre 7/ much as a farmer judges the yield of his crops from appearance of the fields. Outlining the areas of different densities on a map will record their location and will permit estimating the acreage of areas successfully sown. Such examinations are usually made the first and second years after the mustard is sown.

In a first-year examination, experience has shown that four density classes are convenient for use:

Dense: more than 100 plants per milacre
Medium: approximately 26-100 plants per milacre
Sparse: 25 or less plants per milacre
Failed: areas with no mustard

7/ A milacre contains 43.56 square feet, 1/1000th of an acre. It may be either 6.6 feet square, or 3.3 feet wide by 13.2 feet long.

The density of 25 plants per milacre is an important division point, as this is the approximate number of plants usually required to make a blanket flower color that is readily distinguishable at a distance. To account for the entire burned area, the examiner should also record areas missed in sowing, unburned "islands," precipitous and rocky areas, and cultivated and residential areas.

In a second-year examination it may be desirable to recognize additional density classes because of the great increase in plant numbers. The limits of such classes must be decided on the ground by the examiner, as they will depend on the number and development of plants growing, and on the degree of detail desired in the survey.

Observation Plots and Photographs

If it is desired to determine the causes of sparse mustard growth or of its failure to grow in local areas, close observation will be required throughout the growing season. Drouth, desiccating winds, and extreme cold may take their toll of the tender mustard seedlings, or in some cases the mustard may get a good start but fail to mature and produce seed. Observations of the effects of such adverse environmental factors are best made in small plots installed at the time mustard is sown, and checked at frequent intervals.

Paired milacre plots, one sown and the other not sown, afford the best means of studying the growth of mustard and comparing it with native plants in sown and unsown areas. A good plot size is 3.3 feet wide by 13.2 feet long (one milacre), and it is preferable to have the long dimension up-and-down the slope, that is, parallel to the direction of runoff. These may be slope measurements without correction to horizontal distance as would be desirable for larger plots. One plot of each pair should be carefully sown by hand, making sure to sow the same number of seeds per square foot that are sown elsewhere in the burn. The second plot of each pair is left unsown.

As many pairs of plots may be used as are needed to represent the different conditions of soil, aspect, steepness, and altitude, a single pair usually being enough to check each site condition for ordinary observations. The plots of each pair should be spaced at least 25 feet apart to decrease the chances of mustard migration into the unsown plot, especially if observations are to be carried into the second year. Statistical design of the plot installations is not required for these studies because the plots are used to help interpret results of the mustard growth examination in the burned area as a whole, and not as statistical samples of the burn.

Good photographs, repeated at intervals from the same camera stations, will also help by providing a record of the burned area before sowing and the subsequent growth of mustard. Photos in natural color are useful in showing differences in the soil and plant cover, but black-and-white pictures are the most practical for general use.

APPENDIX 1

SPECIFICATIONS FOR THE PURCHASE OF MUSTARD SEED

Rather precise specifications are required to obtain the kind of mustard seed desired for burned area sowing, because of the lack of standardization among common and trade names for the various species and varieties of mustard. The following specifications prepared by the California Forest and Range Experiment Station, assisted by the Regional Fiscal Agent, have been used by the Forest Service in purchasing mustard seed during the last several years. The paragraphs shown constitute only the technical portions of the bid form. Details of quantity, delivery point, adherence to special contractual conditions, etc., are to be supplied by the purchasing agent according to customary procurement procedure.

It is important that samples be drawn immediately on receipt of the seed (see General Specification 5) in order to avoid delay in certifying claims for payment. The seed samples should then be forwarded promptly to the California Seed Laboratory for testing in accordance with Gen. Spec. 5. The penalty clause in Gen. Spec. 6 is included to allow compensation for any seed that might fall below the minimum requirement in germination. The inclusion of such a clause permits sowing the seed immediately on delivery, avoiding delay in starting the sowing job.

Specifications for the two suitable species of mustard are given in paragraphs A and B. In years of normal seed supplies the bid would customarily be worded to invite quotations on only the less costly of the two species of seed. In this case either Specification A or Specification B would be deleted, depending on which species is more readily available or cheaper.

SPECIFICATION A

Mustard seed of the variety known by the common name of Black mustard and known in botanical science as Brassica nigra. This seed is sometimes called "California Trieste (cultivated)", "Red," "Trieste," "Trieste Brown," or "Trieste Red," but the variety desired in this transaction is the brown-seeded kind grown largely in the vicinity of Lompoc, California, and must be certified to have been grown in California.

SPECIFICATION B

Mustard seed of the variety known by the common names of "Montana Trieste," "India" or "Indian" mustard, and known in botanical science as Brassica juncea. This is a brown-seeded variety, the seeds of which resemble but run slightly larger than those of Brassica nigra, and which is produced under cultivation in Montana, Washington, and Oregon. A statement certifying the source of the seed shall be provided.

GENERAL SPECIFICATIONS

1. No bid on any variety of yellow-seeded mustard, either domestic or imported, will be accepted, even though these be designated as varieties of the botanical species Brassica juncea.

2. All seed must be plainly labeled and must otherwise conform to the provisions of the California Seed Law.

3. All seed must be of the .(insert current year) crop, of a minimum purity of ninety-seven percent (97%), and must contain no primary or secondary noxious-weed seeds as designated by the California State Department of Agriculture.

4. Mustard seed must yield a minimum germination of eighty-five percent (85%) in five (5) days, as determined by standard test of the California State Department of Agriculture, on composite samples drawn in accordance with Rules and Regulations under the Federal Seed Act (see pages 11 and 31, Service and Regulatory Announcements No. 156, Production and Marketing Administration, February 1946).

5. On delivery of the seed, samples shall be drawn by a Government officer who will send them to the California Seed Laboratory at Sacramento, California for the standard germination and purity tests. If he wishes, the successful bidder may have a representative present at the time these samples are extracted. The Seed Laboratory will report to the Government and will mail a copy of the report directly to the successful bidder.

6. Should the germinability of the samples, chosen as outlined in the preceding paragraphs, from the seed submitted by the successful bidder, fall below the stipulated minimum percentage, then the payment for the seed will be discounted by one-tenth (1/10) of one cent per pound for each percent below eighty-five (85) in five (5) days, as shown by the tests of the California Seed Laboratory. (Such penalty, if applied e.g. to a hypothetical total purchase of 1000 pounds, would amount to $1.00 for each percent deficiency.)

7. Successful bidder must present with invoice a notarized certificate to the effect that the seed furnished is of at least as high quality in all respects as the minimum requirements noted above.

8. Delivery shall be made within seven (7) days after notice of award is received. NOTICE OF AWARD WILL BE GIVEN SUCCESSFUL BIDDER BY TELEPHONE in order to expedite delivery, and later confirmed in writing. If delivery time herein specified cannot be complied with by bidder, he should specify minimum time required for delivery; otherise, the terms here stated will be mandatory upon successful bidder.

APPENDIX 2

METHOD OF CALCULATING NUMBER OF SEEDS PER POUND AND WEIGHT OF MUSTARD SEED TO BE SOWN PER ACRE

Mustard seed sown in burned areas to date has ranged from approximately 147,000 seeds per pound of Brassica juncea grown in Montana to 280,000 seeds per pound of B. nigra grown in California. At 5 pounds per acre, this would amount to 17 seeds per square foot and 32 seeds per square foot respectively. It is therefore desirable to determine the number of seeds per pound for each lot of seed delivered, and to calculate the weight of seed to be sown per acre in order to attain the desired sowing density of 20 seeds per square foot. This determination is made as follows:

1. Weigh out an exact Apothecaries' dram of mustard seed. (1 dram Apoth. = 0.125 ounce Apoth. = 60 grains[8] = 0.137 ounce Avoir. = 3.888 grams Metric = 0.008571 pounds Avoir.) (Obtain use of scales at a local drug store.)

2. Count the number of seeds in the 1-dram sample. Then, assuming for this calculation that there are 1575 seeds in the sample,

3. $\frac{1575}{.008571}$ = 183,759 seeds per pound (Avoir.)

4. 20 seeds per sq. ft. x 43,560 sq. ft. per acre = 871,200 seeds desired per acre

5. $\frac{871,200}{183,759}$ = 4.74 lbs. (Avoir.) seed required per acre

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8/ The grain is common to Avoirdupois, Troy, and Apothecaries' systems.

APPENDIX 3

INSTRUCTIONS FOR SAMPLING MUSTARD SEED

In sampling any seed it is important to take the samples so that they will be truly representative of the body of seed sampled. The sampling procedure under the Federal Seed Act should be followed.9/ Portions of this procedure that are applicable to mustard seed are briefed as follows:

1. In order to get a representative sample, equal portions shall be taken from evenly distributed parts of the quantity of seed to be sampled; access shall be had to all parts of that quantity.

2. A probe, or trier, long enough to sample all portions of the bag shall be used.

3. As the seed is sampled, each portion shall be examined; if there appears to be a lack of uniformity the portions shall not be combined, but shall be retained as separate samples to determine such lack of uniformity as may exist.

4. When the portions appear to be uniform, they shall be combined to form a composite sample.

5. In quantities of 5 bags or less each bag shall be sampled.

6. In quantities of more than 5 bags, at least every fifth bag but not less than 5 bags shall be sampled.

7. When a shipment consists of more than 200 bags, a separate composite sample shall be taken for each 200 bags or portion thereof.

8. Samples shall be drawn from unopened bags except where the identity of the seed has been preserved.

9. For mustard seed, the minimum weight of sample to be submitted is 5 ounces.

9/ USDA Rules and Regulations Under the Federal Seed Act, Production and Marketing Administration, Service and Regulatory Announcements No. 156, February 1946, pages 11 and 31.

Each sample should be plainly marked with the following data:

Species	Sample number
Name of burn where seed will be sown	Where sampled
Dealer's name	Date sampled
Dealer's lot number	Name of person who did the sampling

The probe is a conical metal tube with tapered point that can be inserted between the meshes of the sacking to allow sampling the seed without opening the sack. When enough seed has been drawn, the probe is pulled out and the hole is closed by pushing the meshes back together. Such a tool can usually be obtained from commercial seed dealers.

If a regular seed probe is not obtainable, an ordinary glass tube can be used. It should have a bore of about 3/16 inch, should be 10 to 12 inches long, and should have the ends fused to dull the sharp, cutting edges. The cylindrical bore of such a tube is a drawback, but seed can be made to run through it satisfactorily if the tube is inserted upward into the sack and then withdrawn with push-pull motions. A glass tube is better than a cylindrical metal one because the operator can see the cause of any stoppage in seed flow. Care should be used to avoid breaking the tube and cutting the operator's hand.

The best containers for mustard seed samples are 5-pound cloth sugar sacks. Ordinary letter envelopes are not satisfactory. Paper bags can be used provided three bags are used for each sample, placing one bag inside another to give a triple thickness of paper around the sample. Each sample should be securely closed to avoid leakage and mixing of the seed, and labelled with full identification data.

APPENDIX 4

DETAILED SUGGESTIONS FOR SOWING BY AIRCRAFT

In the conduct of 11 aircraft sowing jobs, certain procedures have been found superior for getting the job done with efficiency. The following suggestions, based on Forest Service experience, describe the assignment of responsibilities and list the equipment needed for certain workers. They also tell how to adjust the rate of sowing and how to mark the sowing area boundaries, and the methods found best for communication between ground crews and pilots.

Responsibilities

The foreman is responsible for the planning and execution of the work, and for certifying its satisfactory completion. He designates the areas to be sown and supervises their marking. He assists the pilot in setting up an operations base and works closely with the pilot in planning and conducting the job. He determines the number of seeds per pound, calculates the weight of seed to be sown per acre (Appendix 2), and helps the pilot make preliminary adjustment of the seed release mechanism. The foreman supervises communications, and the work of flagmen and ground checkers. He is also responsible for the maintenance of an adequate supply of seed at the operations base, and he keeps track of seed use and acreage sown to guard against running out of seed before the job is done.

Efficient and conscientious flagmen are essential. They work methodically through the burn by prearranged plan, to mark the center of each sowing swath. By appropriate signals they advise the pilot of changes in sowing rate or line of flight required to obtain the proper density and distribution of seed. As time permits between sowing flights, they make counts of the seed sown to supplement the information obtained by the ground checkers. On very large burns it is helpful to have the flagmen plot on their maps the area sown each day, for report to the job foreman.

It is important that flagmen be on location before the first sowing flight of the day and not leave the job until they are signalled to come in. For example, it may have been planned to start sowing at daybreak, but at 10:00 a.m. the plane has not appeared, and the wind has started to rise. The flagman concludes that sowing has been called off, and he leaves his post. However, it might have been not the local wind but some trouble at the airport that caused the delay. Half an hour later the trouble has been corrected, the pilot makes his first flight, and finds no flagman to guide him.

The following equipment for each flagman should be assembled before sowing is begun:

1 bamboo pole, very sturdy, 8 feet long
1 piece white muslin 3 x 5 feet, attached as flag to bamboo pole
1 piece white muslin 3 x 5 feet, with center hole large enough to go over man's head. This is worn like a poncho to make the flagman more readily visible to the pilot.
1 wire frame 12 inches square. This is used in counting the seed sown and may be carried over the arm or around the neck when not in use.
1 knapsack
1 notebook
1 pencil
1 topographic map showing boundaries of burn and sowing areas
1 copy of signals to be used between flagman and pilot

Ground observers, or "checkers," are needed to determine the average density at which seed is being sown within each swath, and to make sure that the swaths meet or overlap to avoid missed areas. In doing this, the checker walks straight across a sown area, and counts the mustard seeds in square foot sample areas. Such counts are made at regular intervals of from 10 to 50 feet, depending on the length of transect and size of the area to be sampled. The sample areas are chosen by dropping a frame of No. 9 telephone wire, 1 foot square, on the ground at random at predetermined intervals.

In checking seed distribution, the steepness of slope at the counting frame must be considered. Perfect distribution of the mustard seed on level ground should give an average of 20 seeds per square foot, with a range of about 10 to 30 seeds per square foot. The desired 20 seeds per square foot is calculated on a horizontal basis. Because the projected area of a one-foot square frame lying on a 100 percent slope is 29 percent less than when the frame is lying on level ground, a count of only 14 seeds within the frame on such steep slopes would still represent correct sowing density.

A ground checker usually works within shouting distance of a flagman, so that the results of his counts can be communicated immediately to the pilot by flag signal if it is found desirable to change the rate of sowing.

The truck driver hauls seed to the operations base, assists in loading the aircraft, operates the airport radio, and keeps a record of the amount of seed sown and the quantity remaining on hand. Each night he reports the seed data to the foreman for use in checking overall seed distribution.

It is customary for the agency in charge of sowing to assist the pilot in obtaining local cooperation in the use of flying fields, clearance for operating in military restricted areas, and in other problems of this nature. In practice, it has also been found best for the sowing agency to store the seed prior to sowing, deliver it to the operations base, and assist as needed in loading it into the aircraft.

Adjustments for Desired Sowing Rate

Before any sowing is done it is necessary to determine the proper setting for the seed metering gate to give the correct rate of flow with the seed to be sown. It is also necessary to determine the optimum height that the aircraft should fly above the ground in order to sow the maximum width of swath. And finally, the optimum flight speed should be determined. These three factors affect the concentration and distribution of the seed, and they vary with different seeds. The determinations are made in ground and flight tests that normally require 3 or 4 hours.

If the pilot has sowed mustard with the same aircraft and seed-release mechanism (hopper, gates, and Venturi flume) he will know the approximate gate settings required to obtain the desired sowing density, and can proceed immediately to the final adjustments in flight.

If the pilot has not had experience with mustard seed in that particular aircraft, an initial test of the seed-flow rate should be made on the ground to determine the approximate setting for the release gate. This setting should then be checked in flight. The ground test is made in two steps:

1. Preliminary calculation

   a. Known: $\frac{43560 \text{ square feet per acre}}{5280 \text{ feet per mile}} = 8.25$ feet, width of swath required to sow 1 acre per mile of flight

   b. Assume: 100 feet = width of swath sown

   c. Then: $\frac{100}{8.25} = 12.12$ acres sown per mile of flight

   d. Known: This lot of seed is to be sown at the rate of 4.74 pounds per acre (Appendix 2)

   e. Then: $4.74 \times 12.12 = 57.45$ pounds of seed to be sown per mile of flight

   f. Known: At 90 miles per hour it takes 40 seconds to go 1 mile

   g. Then: In 40 seconds 57.45 pounds of seed should be released.

2. Seed flow test

a. Put 29 pounds of mustard seed into the hopper

b. Open the seed-release gate and let seed flow for 20 seconds, while operating the seed agitator at flying speed

c. If the metering gate is correctly set, the 29 pounds of seed should pass from the hopper into the Venturi flume in 20 seconds; adjust the gate opening and repeat the test until this approximate rate is attained.

In flight, the rate of seed flow may be changed by vibration or other factors. For this reason, a test must be made while flying to determine the final setting for the metering gate, and to determine the optimum height above ground and speed at which sowing should be done.

The flight test should preferably be made over level or gentle slopes within the area to be sown. But if the sowing area is too remote to permit ready access by the ground checking crew, or if its terrain is too rough, an alternate site must be used.

Alternate sites used to date for the flight test have included a pier extending into the ocean, a sandy beach, and airplane landing fields. Testing at the landing field is most advantageous when sowing by airplane because the pilot can land between flights and observe the results of each test. But care must be used not to broadcast mustard where it might establish itself as an undesirable weed, or in areas from which it might spread to become a nuisance. When such tests are made over an unsurfaced landing field and the seeds germinate and grow, the agency in charge of sowing should accept responsibility for cutting or otherwise destroying the young mustard plants before they become tall enough to constitute a hazard on the runways.

Close observation and counting of the mustard seeds are required to determine the width of swath sown and the number of seeds per square foot within the swath. First, lay on the ground, at 10-foot intervals across the airplane's line of flight, some material that will catch and hold the seeds. Then have the airplane make a sowing flight over the catchment material. Finally, count the number of seeds sown per square foot, and measure the width of swath covered.

For the counting, seed can be caught on long strips of burlap, one-foot squares of cardboard coated with heavy grease, sticky fly-paper, or even a cleanly-swept path in the burned area. The easiest catchment surface to use, however, has been found to be ordinary wax paper coated with fresh varnish or paint.

The pieces of wax paper are cut about 1 foot square and are anchored to the ground at 10-foot intervals for a distance of 150 feet on a line perpendicular to the airplane's line of flight. The papers are then varnished, the sowing flight is made, and the number of seeds per square foot on each paper is determined and recorded. New papers can be quickly placed and varnished for succeeding test flights as needed. Large nails are handy for pegging the corners of each paper to the ground. If the tests are made on the concrete apron at an airport, the papers can be "stuck" down by wetting the concrete with water.

Test flights should be continued with adjustment of the seed-metering gate, the height of the aircraft above ground, and the flying speed until an average sowing density of 20 seeds per square foot, with a range of approximately 10 to 30 seeds per square foot, and a uniform width of swath are attained. The tests should be made in still air because a breeze of even 5 m.p.h. may cause uneven seed distribution and drift.

Marking Boundaries of the Sowing Area

All boundary marking should be completed by the sowing agency before arrival of the airplane. Materials for the markers should be of light color, and durable enough to withstand heavy rain and wind. An inexpensive grade of white muslin is best, but several thicknesses of newspaper can be used. Such markers must be weighted with stones to hold them against the wind. Bentonite and similar soluble powders cannot be relied on to remain visible for several days; they may be washed away by rain.

Twelve-foot squares of cloth or paper make markers of good size for airplane sowing jobs. In open country they should be spaced $\frac{1}{4}$ mile apart; if the sowing boundary is irregular, closer spacing may be required. Markers are more easily seen on prominent ridges than on secondary ridges or in canyons.

Communications

Radio communication between the operations base and vantage points in the sowing area will facilitate large projects of several thousand acres, but is not usually required on the smaller jobs. If radio is used, special operators should be provided because the flagmen and checkers can not handle it in addition to their other duties.

In the sowing jobs done to date, it has not been found desirable to equip the airplane with radio, since visible signals have been adequate for communication between the flagmen and checkers, and the pilot. The signals are made with flags, arms, and airplane maneuver as follows:

a. To inform pilot of flagman's location. Flagman raises flag over head and waves it back and forth in a plane perpendicular to the airplane's line of flight. When the flagman is standing in direct sunlight, the use of a mirror is the best means of signalling a pilot approaching from a distance. An Air Corps signal mirror of the slotted type, about $2\frac{1}{2}$ by 4 inches in size, is most convenient for this use.

b. To inform pilot to fly farther to right or left, to adjust for wind-drift of seed. Flagman holds flag extended upward at 45 degree angle toward side to which pilot should steer.

c. To inform pilot that he is out of seed. Flagman lays flag on ground.

d. To advise pilot to increase the sowing rate. Flagman waves flag back and forth across his knees, to advise pilot to watch closely for arm signal to follow. When pilot acknowledges by wiggling wings and circling, flagman drops flag and extends arms upward at 45 degree angle, Y-fashion, turning to keep facing pilot until signal is acknowledged.

e. To advise pilot to decrease the sowing rate. Flagman waves flag back and forth across his knees, as in d above. When pilot acknowledges, flagman drops flag and extends arms parallel above head, turning to keep facing pilot until signal is acknowledged.

f. Calling-in the flagman. Plane circles flagman or pilot gives some other preferred signal. Sowing operations may be suspended at any hour of the day because of unfavorable weather, low gasoline supply, engine trouble, etc. It is important that the end of sowing be signalled so that the flagman will not be left out on the burn until a messenger can reach him.

APPENDIX 5

SPECIFICATIONS FOR AIRCRAFT SERVICE IN

SOWING MUSTARD SEED[10/]

It is essential that the aircraft used for mustard sowing have enough power for effective and safe operation close to the ground at the altitude at which sowing is done. In addition, there are field responsibilities, and details of organization and operation, that must be clearly understood by the sowing agency and the flying contractor. The job and service specifications given below have been found to be a desirable minimum. Suitable clauses to insure understandings regarding liability, the posting of performance bonds, and certification of the work before payment is made should also be included in the specifications for aircraft service.

GENERAL

The aircraft and such personal services of pilot(s) and mechanics required in these specifications are for use in sowing mustard seed on ..... acres recently burned-over within the ..... National Forest, operating over rugged ground terrain that ranges from ..... feet to ..... feet above sea level, as shown on the map(s) attached hereto.[11/]

Details of the areas to be sown will be furnished by the .....(sowing agency)..... by map and general reconnaissance.

The contractor will be expected to obtain all waivers and authorizations to allow him to operate the aircraft in connection with fulfillment of this contract; however, the .....(sowing agency)..... will assist in any way possible to obtain such authority, waiver, etc., and permits to utilize the best available flying fields.

Flights under this contract involve hazardous combinations of altitude, rugged topography, and weather. Their successful completion requires experienced pilots and good equipment with sufficient power to enable the aircraft to get down into deep and narrow canyons and maneuver without danger of crashing into the canyon walls.

10/ Revised February 1948 by the Forest Service Regional Office, R-5, and the California Forest and Range Experiment Station.

11/ Two maps are usually desirable: (1) section of current C.A.A. Sectional Aeronautical Chart, and (2) topographic map showing area(s) to be sown. The area covered by the topographic map should be clearly indicated on the C.A.A. chart.

SPECIFICATIONS

1. Seed will be furnished by the .....(sowing agency)..... and delivered to the pilot at points agreed upon, in or near the burned area, without cost to the contractor.

2. The .....(sowing agency)..... will provide, without cost to the contractor, adequate storage facilities for the seed up to the time it is loaded into the aircraft; the trucks required to transport seed as needed in conduct of the job; and the man-power required to make the sowing test(s), load seed into the aircraft, and mark sowing boundaries within the burned area.

3. The mustard seed is to be sown at from approximately 3 to 6 pounds per acre, depending upon the size of seed furnished for the job. The determination of seed size and the number of pounds to be sown per acre will be made on the job by the .....(sowing agency).....

4. After award is made to the contractor and prior to actual starting of the sowing, a representative of the .....(sowing agency)..... will, in company with the pilot, conduct a sowing test with the aircraft to be used and will determine the proper adjustment of the seed release mechanism to be used in sowing. Such test(s) should not exceed 4 hours total time. The test(s) will be made at the expense of the contractor in or near the burned area, just before the start of the sowing job.

5. The work is to begin within 10 calendar days after receipt of the contractor's notification to proceed with the job. It is expected that such notification will be given about .....(date).....

6. The work is to be completed as rapidly as flying conditions permit. It is assumed that from 3 to 5 early morning hours will be the best for flying, owing to adverse air conditions that may prevail later in the day.

7. The contractor will be required to provide the stipulated aircraft licensed by the Department of Commerce in approved mechanical condition, together with all equipment required for proper and complete fulfillment of the service requirements as outlined in and made a part of these bid specifications.

8. During any part of the period covered by the contract, the decision of an inspector from the Civil Aeronautics Administration, Department of Commerce, as to the serviceability of the aircraft will be accepted as final.

SERVICE REQUIREMENTS

The aircraft supplied shall:

1. Be equipped with engine(s) capable of developing at least 150 h.p. up to the maximum altitude at which sowing will be done.

2. Have a minimum pay-load capacity of 400 pounds with a service ceiling of at least 10,000 feet.

3. Be equipped with seed hopper and seed releasing mechanism capable of adjustment to provide uniform ground distribution of from 10 to 30 mustard seeds per square foot, final adjustment to be made on the job with the seed that is actually to be sown.

4. Be equipped with adequate safety devices for the protection of (employee of the sowing agency) should it be necessary for him to accompany a flight.

Fixed-wing aircraft

5. Airplanes in first class condition with low-time engine(s) capable of developing a rated 200 h.p., a payload of at least 500 pounds, and a service ceiling of 10,000 feet or more are preferred. Such pay load shall include only the weight of the cargo furnished by the (sowing agency).

6. Experience has shown that the flight elevation above ground while sowing should not exceed 300 feet.

Rotary-wing aircraft

7. The helicopter supplied shall be adequately powered for jump take-off, hovering with ground effect, spot landing, and safe operation at elevations up to 5,000 feet, with minimum of 175 pounds pay load in excess of flight crew and fuel for 45-minute flight.

8. Experience has shown that the seed should be broadcast at a height of about 50 feet above the ground.